FORAGE & GRAZING LANDS

Forage Yield and Persistence of Chicory and English Plantain

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ABSTRACT

Graziers in the northeast USA often face forage shortages in midsummer. Chicory (*Cichorium intybus* L.) and English plantain (*Plantago lanceolata* L.) have been introduced in the USA as sumer-active perennial herbs for pastures. We conducted two experiments at Rock Springs, PA, to evaluate chicory and plantain for yield and persistence under clipping. 'Grasslands Puna', 'Lacerta', and 'Forage Feast' chicory, and 'Ceres Tonic' and 'Grasslands Lancelot' plantain were sown in field plots in May 1997 (Exp. 1) and 1999 (Exp. 2). Plots were cut every 3 or 5 wk in 1998 and 1999 in Exp. 1 and every 4 wk during 2000 and 2001 in Exp. 2. Dry matter yield was determined at each harvest. Stand densities were determined in each experiment. Forage Feast chicory yielded 25% less than Puna (6000 vs. 8100 kg dry matter ha^{-1}; $P < 0.05$) in 1998, whereas yields of both cultivars were similar ($P > 0.05$) in 1999 and 2000. Lacerta chicory yielded 9 to 16% less than Puna and Forage Feast in Exp. 2. Forage Feast and Puna chicory had 20 to 50% stand loss in Exp. 1 and 40 to 60% stand loss in Exp. 2. Lacerta chicory lost 80% of the stand during Exp. 2. The plantain cultivars yielded 6 to 14% less dry matter than Puna chicory in 1998 and 33 to 39% less in 2000. Both plantain cultivars, however, suffered a nearly complete loss of plants during the second winter after establishment in both experiments. Ceres Tonic and Lancelot plantain are not suited for the northeastern USA.

Perennial cool-season grasses predominate in pastures and haylands of the northeastern USA (Baylor and Vough, 1985). Growth of these grasses follows the well-known bimodal distribution of rapid growth in late May and early June, reduced growth during July, August, and early September, and increased growth in the fall. Farmers would like productive forage crops for the summer period. Grasslands Puna chicory is an alternative forage with good drought tolerance and production in summer (Jung et al., 1996; Volesky, 1996; Collins and McCoy, 1997; Li et al., 1997a,b). Chicory has high digestibility and a low fiber concentration, which are desirable for growing and lactating ruminants (Turner et al., 1999). Newer varieties of chicory are available, but information on their use and productivity is limited.

English plantain (buckhorn plantain, narrow-leaf plantain, ribwort, ribgrass) commonly occurs as an occasional weed in temperate pastures (Grime et al., 1990). It is described as deep rooting, drought resistant, and a palatable pasture plant (Ivins, 1952; Sagar and Harper, 1964; Foster, 1988). Cultivars of plantain have been selected for grazing in New Zealand (Stewart, 1996; Rumball et al., 1997). The ecology of natural populations of plantain and its biology as a weed have been investigated (Bassett, 1973; Kuiper and Bos, 1992). Apart from older reports in the scientific literature, the forage value of plantain is relatively unknown. We have investigated the seedling development and establishment of plantain and found that it establishes easily from seed (Sanderson and Elwinger, 2000a,b). There are some reports of medicinal attributes for plantain, such as anthelmintic properties, but the research is not conclusive (Knight et al., 1996; Gustine et al., 2001).

Establishing complex pasture plant communities has received renewed attention (Sanderson et al., 2001). In New Zealand, pastures seeded with a mixture of 18 to 26 species consisting of cool-season grasses and legumes along with several pasture herbs, including chicory and plantain, yielded more dry matter under sheep grazing than did perennial ryegrass (*Lolium perenne* L.)–white clover (*Trifolium repens* L.) mixtures (Ruz-Jerez et al., 1991; Daly et al., 1996). The increased production resulted from greater forage growth during the summer, contributed mainly by the forb component (mostly chicory). In Scotland, trials with several mixtures of forbs, grasses, and white clover under low-input management for hay production showed that plantain competed well with grasses (Fisher et al., 1996). North American research indicates that chicory persists in mixtures with other cool-season forages and increases late season herbage production (Belesky et al., 1999; Kunelius and McRae, 1999).

The objective of our research was to determine the persistence and productivity of chicory and plantain. The first phase of this research focused on seedling establishment and development (Sanderson and Elwinger, 2000a,b). We report here on the second phase of the research in which both species were evaluated in clipped plots. Future reports will focus on the third phase in which the species were evaluated under grazing and for nutritive value.

MATERIALS AND METHODS

Two field studies were conducted at the Russell E. Larson Agricultural Research Center near Rock Springs, PA. Soil at the site was a Hagerstown silt loam (fine, mixed, semiactive, mesic Typic Hapludalfs). Weather data (Table 1) were obtained from monitoring stations within 1 km of the experimental site.

Experiment 1

Tonic and Lancelot plantain and Puna, Forage Feast, and Lacerta chicory were seeded with a plot drill in 3.6- by 6.1-m plots on 16 May 1997 in a clean tilled seedbed. Plantain was seeded at 11 kg ha^{-1}, and chicory at 4.5 kg ha^{-1}. Seeding depth

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Table 1. Air temperature, rainfall, and soil moisture at Rock Springs, PA, during the growing seasons of 1998, 1999, 2000, and 2001.

Month	Average monthly air temperature					Rainfall					Soil moisture			
	1998	1999	2000	2001	30-yr avg.†	1998	1999	2000	2001	30-yr avg.	1998	1999	2000	2001
	°C					mm					m^3m^{-3}			
April	10.0	9.0	8.6	9.4	8.7	172	94	74	62	74		0.34	0.34	0.34
May	17.0	15.1	15.9	14.4	14.8	116	37	62	35	92		0.21	0.24	0.18
June	18.5	19.2	19.7	19.3	19.5	131	104	97	138	102	0.34	0.18	0.29	0.25
July	20.7	22.9	18.9	19.5	21.8	89	61	53	59	92	0.31	0.18	0.25	0.26
Aug.	20.9	19.4	19.1	21.3	20.9	71	146	74	91	81	0.26	0.23	0.28	0.22
Sept.	18.6	16.9	15.1	15.1	16.8	44	133	48	80	82	0.19	0.30	0.23	0.24

† Data for the 30-yr average are from Waltman et al., 1997.

was ≈1 cm. Lacerta did not establish and was dropped from the experiment. Soil tests in 1997 indicated a pH of 6.3, 59, and 220 kg ha^{-1} of available P and K, respectively. Plots were fertilized with 27 kg P and 72 kg K ha^{-1} in October 1997 and April 1999. Fertilizer N was applied at 56 kg ha^{-1} in June and July of 1998 and 1999.

The plots were divided lengthwise. One-half was harvested every 3 wk and the other half every 5 wk during 1998 and 1999 (Table 2). Plots were rated at each harvest for the percentage of plants that were bolted (chicory) or exhibited scapes (flower stalks in plantain). At each harvest, a 0.5- by 4.6-m strip was cut to a 7-cm height with a rotary mower equipped with a collection bag. The entire sample was dried at 55°C for 48 h to determine forage dry matter yield. Plants were counted in two 0.1-m^2 quadrats in each plot in May of 1999 and 2000.

The design of the experiment was a split-plot arrangement of treatments in a randomized complete block with five blocks (replicates). Whole plots were the forage entries and subplots were harvest frequencies. Analysis of variance was conducted on total seasonal forage dry matter yield. A combined analysis of variance indicated significant interactions among years and forage entries, therefore separate analyses were conducted for each year. The MIXED procedure of the SAS Institute (1998) was used for the analysis. The forage entries and harvest frequencies were treated as fixed effects and blocks were treated as random effects. Separate analyses of variance were conducted on the plant density and bolting data for each date. Planned comparisons of (i) the average of chicorys vs. the average of plantains, (ii) Lancelot plantain vs. Tonic plantain, and (iii) Puna chicory vs. Forage Feast chicory were used to compare treatment means.

Experiment 2

A second field study was planted on 28 Apr. 1999 with the same species and cultivars used in 1997. The field site was adjacent to the 1997 planting. Plot size was 1.8 by 4.6 m and cultural methods were the same as for the 1997 planting. Soil tests in 1999 indicated a pH of 6.1 and 87 and 120 kg ha^{-1} of available P and K, respectively. Limestone was applied at 4.5 Mg ha^{-1} in April 2000. Fertilizer N was applied at 56 kg ha^{-1} in April, June, and July of 2000 and 2001. Forage dry matter yield was measured every 4 wk during May to August 2000 and 2001 (Table 2). Harvest procedures were the same as for the 1997 experiment except that the mowed strip size was 0.5 by 4 m. Plants were counted in two 0.1-m^2 quadrats per plot in October 1999, October 2000, June 2001, and September 2001. Plots were rated at each harvest for the percentage of plants that were bolted or exhibited scapes. Plots were also rated at each harvest for the amount of weed invasion (as a percentage of the total plant mass in the plots). In late March 2001, significant heaving was noted in several plots and all plots were visually rated by two observers for heaving on a scale of 1 (little or no heaving) to 5 (nearly all plants heaved).

Table 2. Harvest dates of chicory and plantain in 1998, 1999, 2000, and 2001. Forages were harvested every 3 or 5 wk in 1998 and 1999. Harvests were every 4 wk in 2000 and 2001.

1998		1999			
3 wk	5 wk	3 wk	5 wk	2000	2001
19 May	19 May	20 May	20 May	16 May	4 June
10 June	24 June	10 June	24 June	14 June	3 July
30 June	29 July	1 July	29 July	11 July	31 July
21 July	2 Sept.	22 July	2 Sept.	8 Aug.	5 Sept.
11 Aug.	7 Oct.	12 Aug.	7 Oct.	5 Sept.	
2 Sept.		2 Sept.			
23 Sept.		23 Sept.			

The design of the experiment was a randomized complete block with five blocks (replicates). Analysis of variance was conducted on total seasonal forage dry matter yield. A combined analysis of variance indicated significant interactions among years and forage entries, therefore separate analyses were conducted for each year. The MIXED procedure of the SAS Institute (1998) was used for the analysis. The forage entries were treated as fixed effects and blocks were treated as random effects. Separate analyses of variance were conducted on the plant density, bolting, and weed data for each date. Planned comparisons of (i) the average of chicorys vs. the average of plantains, (ii) Lancelot plantain vs. Tonic plantain, (iii) Puna chicory vs. other chicorys, and (iv) Forage Feast chicory vs. Lacerta chicory were used to compare treatment means.

RESULTS AND DISCUSSION

Weather

The spring of 1998 was warm and wet, whereas summer temperatures were near the long-term average and rainfall was slightly below average (Table 1). In 1999, temperatures were near the long-term average, whereas rainfall was below average in May and July, but much above the long-term average in August and September. Despite lower rainfall in 2000 than 1999, soil moisture levels in 2000 tended to be higher than in 1999. The lower temperatures during the summer of 2000 may have reduced evapotranspiration compared with 1999 and spared soil moisture. Temperatures were near the long-term average in 2001, whereas rainfall was below average in May and July.

Dry Matter Yields

There was no interaction between cutting frequency and forage species or cultivar for dry matter yield in 1998 or 1999 (data not shown); therefore, means of the

two cutting frequencies are presented (Table 3). The 5-wk cutting frequency resulted in higher dry matter yields for chicory and plantain. Under New Zealand conditions, grazing Puna chicory every 4 wk produced more herbage mass (9600 kg ha^{-1}) than grazing at 1- or 2-wk intervals (4800 and 6400 kg ha^{-1}, respectively; Li et al., 1997a). Similar results were reported in grazing research from Oklahoma where Puna chicory yielded 7900 kg ha^{-1} when rested for 5 wk between grazings vs. 6600 kg ha^{-1} when rested for 2 or 4 wk between grazings (Volesky, 1996). Puna chicory yielded 22% more under 6-wk compared with 3-wk frequency in West Virginia (Belesky et al., 1999). On the other hand, previous research at Rock Springs during a 2-yr period showed inconsistent responses of Puna chicory to different clipping management frequencies. In the first year after establishment, yields of chicory were similar when harvested 3, 4, or 6 times, whereas in the second year, the three-cut system produced 30% more dry matter than the 4- or 6-cut systems (Jung et al., 1996). Nitrogen and cutting frequency in that study, however, were confounded with the frequent cutting system receiving up to 300 kg N ha^{-1} and the infrequent system only 200 kg N ha^{-1}. Nutritive value of the herbage should also be considered when comparing yields from the 5- and 3-wk cutting frequencies. Older herbage may have a lower nutritive value, which may offset any gains in dry matter yield.

Forage Feast chicory yielded 25% less ($P < 0.05$) than Puna chicory in 1998, whereas forage yields of both cultivars were similar ($P > 0.05$) in 1999 and 2000 (Table 3). Lacerta chicory yielded 9 to 16% less than Puna and Forage Feast chicory in Exp. 2 during 2000 and 2001, respectively. The plantain cultivars yielded less than chicory in both experiments. The plantains did not survive into 1999 or 2001 for Exp. 1 and 2, respectively, thus no yield data were available for those years. Yield of plantain in 2000 was 26% less than in 1998, whereas yield of chicory was slightly higher in 2000 compared with 1998. Rainfall and soil moisture were lower in 2000 than in 1998 (Table 1), which may account for these yield differences. This indicates, however, that plantain does not yield as well in dry years compared with other forage crops. In a separate experiment conducted adjacent to this site, Sanderson et al. (2002) reported yields of 9700 kg ha^{-1} in 1998, 7700 kg ha^{-1} in 1999, and 7200 kg ha^{-1} in 2000 for 'Pennlate' orchardgrass fertilized with 112 to 168 kg N ha^{-1}. Jung et al. (1996) reported that Puna chicory fertilized with 200 to 300 kg N ha^{-1} yielded 9400 kg ha^{-1} compared with 7900 kg ha^{-1} for Pennlate orchardgrass fertilized similarly. Stewart (1996) in New Zealand reported yields of 7682 kg ha^{-1} for Lancelot plantain and 8362 kg ha^{-1} for Tonic plantain compared with 9862 kg ha^{-1} for orchardgrass.

Table 3. Forage dry matter yields† of chicory and plantain during two experiments at Rock Springs, PA.

	Exp. 1		Exp. 2	
Entry	1998	1999	2000	2001
	— Dry matter yield, kg ha^{-1} —			
Grasslands Puna Chicory	8100	7300	8200	5800
Forage Feast chicory	6000	7600	8300	5400
Lacerta chicory			7500	4700
Grasslands Lancelot grazing plantain	7500		5500	
Ceres Tonic grazing plantain	7000		5000	
SE	333	234	266	237
3-wk cutting interval	6700	7000		
5-wk cutting interval	7600	7800		
SE	176	218		
Planned contrasts				
Chicory vs. plantain	ns‡		**	
Lancelot vs. Tonic plantain	ns		ns	
Puna vs. other chicorys	**	ns	ns	*
Forage Feast vs. Lacerta			**	**

*Significant at the 0.05 probability level.
**Significant at the 0.01 probability level.
†Dry matter yield data in 1998 and 1999 are averages of two cutting intervals and five replicates. In 2000 and 2001, dry matter yield data are means of five replicates for a 4-wk cutting interval.
‡ns = not significant.

Persistence of Plantain and Chicory

The plantain cultivars survived during the first winter in Exp. 1 and 2. Visual observations in 1998 indicated an adequate stand of both plantain cultivars in Exp. 1. In Exp. 2, plant density ranged from 187 to 290 plants m^{-2} in 2000 (Fig. 1). Both plantain cultivars, however, suffered a nearly complete loss of plants during the second winter. Although Lancelot plantain maintained ≈100 plants m^{-2} in June 2001, the surviving plants were

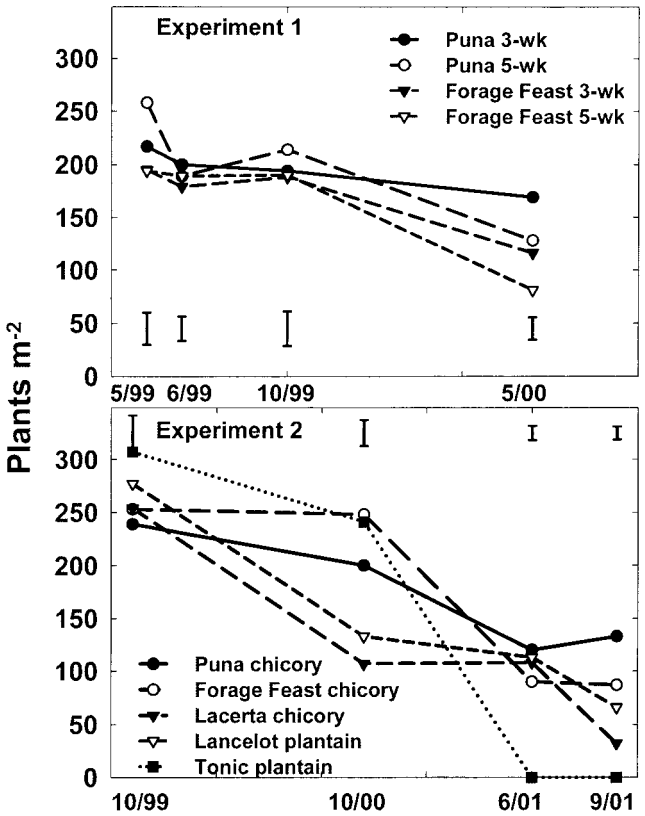

Fig. 1. Plant density of chicory and plantain cultivars during Exp. 1 and Exp. 2 at Rock Springs, PA. Bars indicate one SE unit.

very small, weak, and did not compete with weeds (mainly dandelion, *Taraxacum officinale* F.H. Wigg. group) or contribute to dry matter yield. The combination of weed competition and winter weather conditions probably contributed to stand decline. In the Netherlands, the half-life of plantain growing on roadsides, pastures, or hayfields ranged from 1 to 7 yr with an average of 2.7 yr (Mook et al., 1992). Other research has shown that plantain populations decreased greatly in mixture with sweet vernalgrass (*Anthoxanthum odoratum* L.) after fertilizer application because of strong interspecific competition (Berendse, 1983). Plantain has not persisted more than 2 yr in simple or complex mixtures with grasses and legumes in our research (B.F. Tracy and M.A. Sanderson, 2002, unpublished data).

In March 2001, a great deal of frost heaving was noted in the chicory plots, which may have contributed to plant loss. Mean visual ratings for Puna, Forage Feast, and Lacerta were 4.2, 4.8, and 5.0, respectively. Stand declines and heaving may have been related to winter temperatures and snow cover.

Forage Feast and Puna chicory had stand losses of 20 to 50% during 1999 to 2000 in Exp. 1 (Fig. 1). All three chicory cultivars had ≈250 plants m^{-2} at the end of the seeding year in 1999 for Exp. 2. Puna chicory maintained a relatively dense stand (150 plants m^{-2}) into 2001, whereas Lacerta had <50 plants m^{-2} in September 2001 and Forage Feast chicory had 100 plants m^{-2}. Pure stands of Puna chicory lost one-third of the plant population during the first year in New Zealand (Li et al., 1997a). A minimum density of 25 chicory plants m^{-2} was needed for adequate herbage production because chicory compensated for some stand loss by producing additional shoots. Chicory composition of mixed species [orchardgrass, chicory, and birdsfoot trefoil (*Lotus corniculatus* L.)] swards in West Virgina declined from 80 to 20% of the sward under 3 yr of clipping management (Belesky et al., 1999). High N rates also influenced chicory stand decline. After 3 yr, chicory had declined to 40% of the stand in unfertilized swards, whereas swards fertilized with 480 kg N ha^{-1} had <5% chicory (Belesky et al., 2000).

Weeds became a problem in chicory and plantain plots during the summer of 1998 in Exp. 1. Visual ratings of weeds present (rating of 1 = little or no weed cover; 10 = complete weed cover) indicated that weeds {*Setaria glauca* (L.) P. Beauv. [= *Pennisetum glaucum* (L.) R. Br.] and *Digitaria sanguinalis* (L.) Scop.} were abundant in Forage Feast chicory (rating = 4.7), Tonic plantain (rating = 6.2), and Lancelot plantain (rating = 8.4). There were few weeds in the Puna chicory (rating = 1.0) plots. Plots of Lancelot and Tonic plantain suffered a major weed invasion during the late summer of 2000 in Exp. 2, as measured by visual estimates of weeds in the stand (Table 4). The predominant weeds were *D. sanguinalis* and *S. glauca*. The weed invasion may have resulted from the decline in plant density or the weed competition could have hastened stand decline. There was a low percentage of weeds in the chicory plots; however, Lacerta chicory had 15% weeds in September 2000. In 2001, weed percentage in both Lacerta and Forage Feast chicory increased during the growing season, reflecting the loss of chicory plants during this time. Weed percentage was low in Puna chicory in both years. West Virginia research suggested that chicory should be grown in mixed swards to reduce potential invasion of weeds and to enhance the nutritive value of mid- to late-summer forage in pastures (Belesky et al., 1999, 2000). Our results confirm that recommendation and clearly show that weed invasion accompanies stand declines in monocultures of chicory.

Puna chicory was developed from plant populations from New Zealand (Rumball, 1986). Forage Feast chicory was developed in France (J. Baert, 2002, personal communication). Lacerta was developed in Uruguay from germplasm collected in Argentina (Castellano-Cantero, 1997) and is a biennial but can be maintained in grazed swards if allowed to reseed (Formoso, 1995). Lancelot plantain was developed out of plant collections from pastures on the North Island of New Zealand, whereas Tonic plantain was selected from germplasm collected in northern Portugal (Stewart, 1996; Rumball et al., 1997). Forage Feast chicory, Lacerta chicory, and

Table 4. Visual estimates of the percentage of weeds in herbage dry matter at each harvest during 2000 and 2001 of Exp. 2 at Rock Springs, PA.

	2000					2001			
Entry	May	June	July	Aug.	Sept.	June	3 July	31 July	Sept.
	% weeds								
Grasslands Puna Chicory	0	0	1	1	1	1	5	2	2
Forage Feast chicory	3	1	1	1	1	2	13	23	19
Lacerta chicory	3	1	1	4	15	3	22	70	73
Grasslands Lancelot grazing plantain	3	2	6	45	48				
Ceres Tonic grazing plantain	3	3	7	34	34				
SE	0.7	0.6	1.6	6.9	7.4	0.6	4.6	7.6	6.0
	Planned contrasts								
Chicory vs. plantain	**	**	**	**	**				
Lancelot vs. Tonic plantain	ns†	ns	ns	ns	ns				
Puna vs. other chicorys	**	ns	ns	**	**	**	**	**	**
Forage Feast vs. Lacerta	ns	ns	ns	**	**	ns	ns	**	**

* Significant at the 0.05 probability level. Significance was assessed on a $\log_{10}$ transformed scale.
** Significant at the 0.01 probability level. Significance was assessed on a $\log_{10}$ transformed scale.
† ns = not significant.

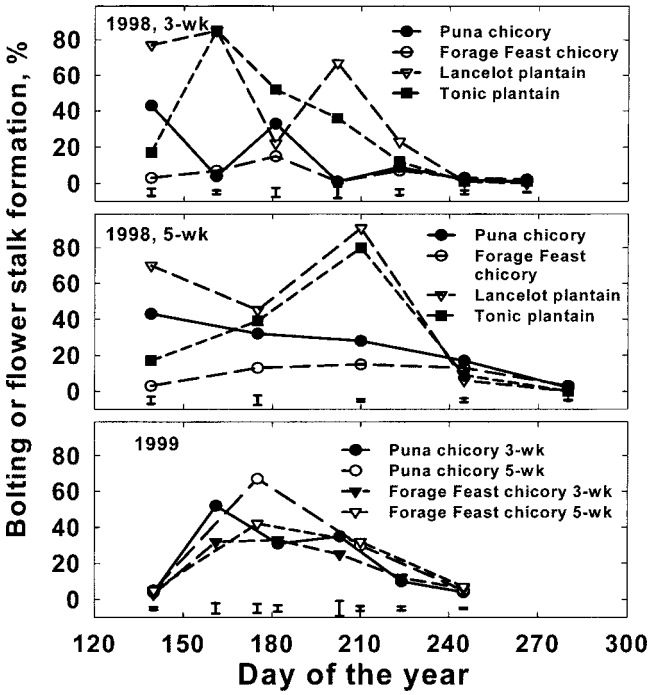

Fig. 2. Percentage of chicory cultivars bolting or plantain cultivars exhibiting scapes during 1998 and 1999 of Exp. 1. Bars indicate one SE unit.

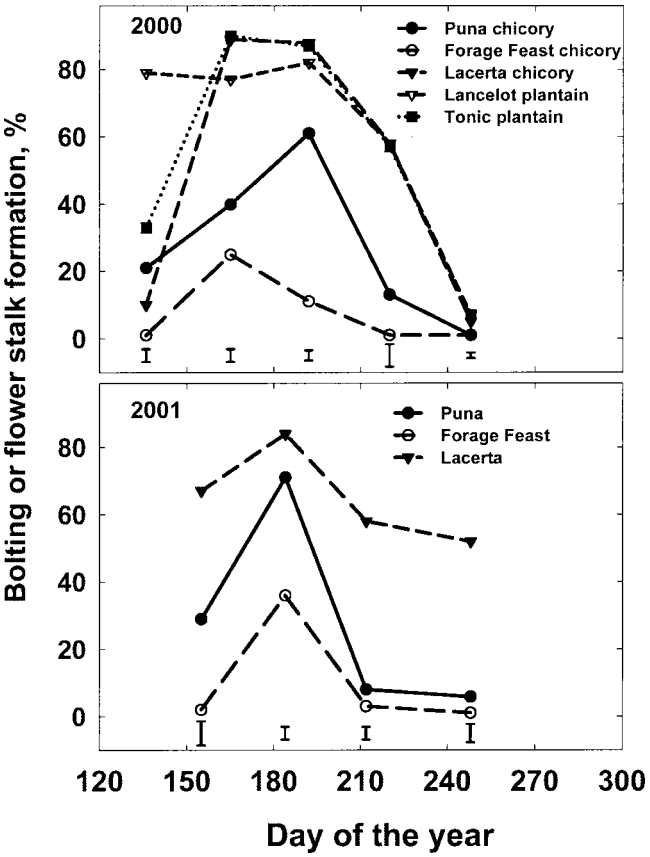

Fig. 3. Percentage of chicory cultivars bolting or plantain cultivars exhibiting scapes during 2000 and 2001 of Exp. 2. Bars indicate 1 SE.

Tonic plantain, because of their genetic backgrounds, probably are adapted to milder climates than the northeastern USA and are susceptible to winterkill. Controlled environment research in our laboratory has shown that cold tolerance differs among the chicory and plantain cultivars with a ranking of Puna chicory > Lancelot Plantain > Tonic plantain (Skinner and Gustine, 2002).

Bolting and Flower Stalk Formation

Both plantain cultivars flowered prolifically from May to July in 1998 and 2000 (Fig. 2 and 3). Lancelot plantain produced a large number of scapes earlier than Tonic plantain in both years. Puna chicory bolted more than Forage Feast in both Exp. 1 and 2. Lacerta chicory bolted more than Puna and Forage Feast in 2000 and 2001. Cutting frequency did not seem to affect the amount of bolting in Forage Feast, which had <20% bolting in 1998 and 2000 to 30% bolting in 1999.

The amount of bolting was greatest in May and June for Puna and Forage Feast chicory, whereas Lacerta chicory and both plantain cultivars produced flower stalks throughout the growing season (Fig. 2 and 3). The flower stalks in chicory originate from the apical meristem, whereas in plantain the flower stalks arise from axillary buds and the apical meristem remains vegetative (Soekarjo, 1992). Thus, flower stalk formation in plantain may be less affected by clipping than in chicory. Chicory and plantain are long-day plants, thus the greatest amount of reproductive growth would be expected during May to July in central Pennsylvania when daylengths range from 14 to 16 h. About 50 to 70% of uncut Puna chicory plants bolted during May and June in a multilocation study in West Virginia (Clapham et al., 2001). Bolting of Puna chicory was greatest in spring in Oklahoma research and increased with less frequent defoliation (Volesky 1996). Flower stalk formation reduces the nutritive value of chicory and plantain (Barry, 1998; Wilman et al., 1997).

CONCLUSIONS

Our results suggest that plantain lacks suitable persistence for use in the northeastern USA. Chicory yielded more and persisted better than plantain although significant stand losses occurred. Managing the spring reproductive growth of chicory would be a challenge for graziers. Forage Feast chicory had significantly less bolting than other chicory cultivars, which may reduce herbage waste from ungrazed stems. This advantage, however, may be offset by its reduced persistence. Lacerta chicory does not appear well suited for use in the northeastern USA because of poor persistence and a high degree of bolting.

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